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Mechanizing the Harvest
OF RED TART CHERRIES

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MECHANIZING THE HARVEST OF RED TART CHERRIES

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MICHIGAN'S AVERAGE ANNUAL production of red tart cherries is approximately 71,000 tons. The average "farm value" of this crop is almost $10 million. New York, Wisconsin, Pennsylvania, Oregon, Utah, Washington, Colorado and other states produce enough additional cherries to make the average U. S. production about 130,000 tons, the "farm value" of which is approximately $20 million.

Compared to other tree fruits in size cherries are relatively small, and hand picking is slow, tedious work. It normally takes about 10 times as many man hours to pick a ton of cherries as it does to harvest a like amount of apples, peaches or pears. The fact that the season is short and per-worker yield comparatively small means that large numbers of pickers are required.

Records kept by the Michigan Employment Security Commission show that it takes about 45,000 workers to harvest the Michigan crop. Sufficient local help is not available in cherry producing areas, and when harvest time comes it is necessary to recruit approximately 35,000 pickers from other parts of Michigan, other states and foreign countries. In the past, these workers and the ones who served other cherry producing states came regularly and followed well-defined routes. Many of the pickers, however, who formerly came during the harvest season have found or are finding year-around employment which eliminates them from working as harvest hands. This means that the streams of migrant pickers once flowing through the cherry producing areas of the United States are rapidly drying up.

While the supply of domestic help was once adequate, the problem has become so acute that it is now necessary to bring in workers from foreign countries. Many of the pickers (both foreign and domestic) lack experience and tend to be incompetent. This means that they require more supervision than did the migrants. In spite of this fact, they demand improved housing and higher wages.

At present, approximately half of the total amount of money spent to produce a crop of cherries goes for harvesting. Costs are almost sure to go still higher if human pickers continue to do the work. A less expensive and more effective means of harvesting will have to be found if the industry is to prosper.

Mechanization has solved other fruit production and handling difficulties and this approach appears to offer the only reasonable hope of providing an answer to cherry harvesting.

PURPOSE OF THE WORK

The purpose of the work here reported was to develop equipment and methods that would 1) reduce the number of human pickers required, 2) lower picking costs and 3) help to maintain on-the-tree quality.

HOW THE STUDY WAS MADE

The experimental work was started during the 1956 harvest season when a variety of hand and pole shaking methods were tried. The object was to develop a quick and effective means of separating red tart cherries from the trees on which they grew. None of the methods tried that year proved satisfactory.

In 1957 several types of mechanical shakers and a cloth-covered metal frame were used in separating and collecting the fruit. Although they were more effective, the shakers and the collecting units still left much to be desired.

Early in 1958 a tractor-mounted hydraulically-activated boom-shaker[1] that had been developed in the West for harvesting nut crops was made available for experimental use. It proved the most effective yet and enabled operators to separate in seconds amounts of fruit that had formerly required minutes. Improvements were made in the design of the fruit collecting units and the results achieved in the experimental orchards led to the conclusion that mechanical picking was ready for trial under commercial conditions.

[1]Manufactured by Gould Brothers, Inc., San Jose, California.

During the 1959 season, hydraulic boom-shakers and several types of collecting units were tried in commercial cherry plantings. Several orchards were involved and trials were conducted in Michigan's principal cherry producing areas. The 3,000 trees harvested with machines yielded more than 150,000 pounds of fruit. Time and cost studies were made, yield records were kept and quality studies were conducted both in the field and at the processing plants where the machine-picked fruit was packed.

HANDPICKING METHODS ANALYZED

The Method. Cherries have been picked by hand for many years. In this method a picker usually accumulates several cherries in his hand and then transfers them to an 8 or 10-quart pail held at waist or chest height by web straps. Some cherries are stripped from the trees with the fingers and permitted to fall directly into the picker's pail. Although many cherries are picked from the ground, ladders must be used to harvest most of them. Picking usually requires from 6 to 10 settings of the ladder in each tree. The harvested cherries are usually carried to an orchard trailer or truck where they are poured into lugs, or tanks containing cold water. Some "field sorting" is usually done as the fruit is poured from the pickers' pails. When a load has been accumulated it is hauled to a receiving station or processing plant.

Picking Rates. Performance of pickers varies widely. The average worker harvests about 300 pounds per day for which he is paid a piecework rate of about 2½ cents per pound. When the crop is light, the pickers usually demand higher rates. On the average, a picker drops or spills about 4 percent of the cherries and leaves approximately 1 percent on the tree. This means that the total amount of fruit recovered is about 95 percent.

Damage to Fruit and Tree. Most pickers bruise fruit rather severely, which leads to scald and other blemishes which lower grade and impair keeping quality. Setting ladders and climbing through the trees cause damage to both trees and fruit.

Costs. The ladder, pails and straps used cost about $15 and seldom last more than five years. When equipment, housing and supervision costs are added to what is spent for labor, the total cost of harvesting is approximately 3 cents per pound.

MECHANIZATION—EQUIPMENT AND METHODS

Separating Equipment

The first step in mechanical harvesting is the separation of the fruit from the tree. It was found that selective picking (choosing the individual fruits to be harvested) was impractical. Early in the trials it was found that cherries could be removed by striking or shaking the limbs.

Handshaking—A variety of hand and pole shaking methods were tried in 1956. These included handshaking limbs of various sizes, using hand-held pole shakers (See Fig. 3 page 10) with various types of hooks at the ends, and short lengths of rubber hose to strike the branches. Although cherries could be separated from the tree by these methods, the work was exhausting and the methods were impractical.

Hand-held Mechanical Shakers—During the 1957 season, several types of mechanical shakers were tried. These hand-held units were hooked to or held against individual limbs (See Fig. 4 page 11). Because of the weight and the fact that it was often necessary to hold the units at shoulder height, the work also was exhausting. Much of the shock was transferred to the workers' arms adding to the difficulty. Only small branches could be picked successfully in this way and production rates were low.

Boom-Type Shaker—In 1958 a tractor-mounted hydraulically-activated boom-shaker was tried (Fig. 1). This unit consisted of a tractor-mounted boom with a claw (clamp) at the end (Fig. 2). It could be maneuvered so that the claw could be closed on main scaffold limbs. Once in position the operator could shake the limb by activating the boom. Under favorable conditions this was the most effective means tried and enabled workers to separate approximately 95 percent of the fruit. Production rates and costs are discussed later in this report.

The best method of operation was to back the boom past the first tree in a given row. It was then moved forward into this tree and attached, in turn, to each of the main scaffold branches. In making the attachments the tractor remained in approximately the same position. When the first tree had been finished, the tractor was backed past the second tree in the row and then moved in as before. Subsequent trees were handled in the same way until the row had been completed.

Strokes of ½, 1, 1½ and 2 inches were tried. In each case the fre-

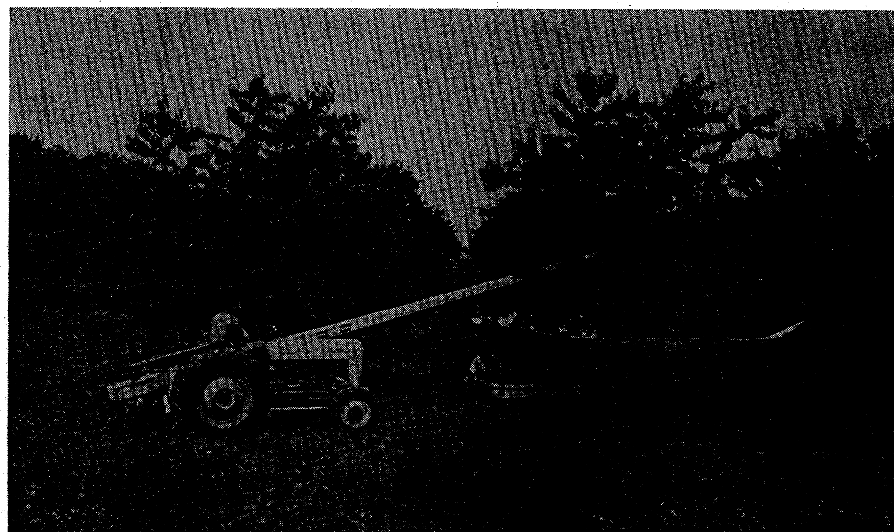

Fig. 1. This type of tractor-mounted boom shaker and canvas-covered collecting unit was used experimentally in 1959.

Fig. 2. A close up of a rubber covered "claw" by means of which the boom shaker was attached to scaffold branches. It could be opened and closed.

quency was varied from 500 to 900 cycles per minute. Best results were obtained when a 1½-inch stroke was used at 800 cycles.

Shaking periods of from 3 to 5 seconds gave the best results. Longer periods did not increase the yield but did separate more trash, increase the amount of bruised fruit and cause more bark damage.

In harvesting heavily loaded limbs shaking time should be broken into two or three 1- or 2-second intervals with a short period between each of them. This allows the cherries to roll off the collecting surface and thereby avoids undue strain on the collecting units and helps minimize pocketing and reduces bruising.

The claw should be attached to a limb in such a way that the angle between it and the boom is 90° or as near this as possible. To make such an attachment, however, is not always practical. When the angle deviates from 90°, a force is created which may cause the claw to slip and damage the bark.

The points at which attachments should be made depend upon branch size, distribution of fruit, visibility and the angle which the limb makes with the boom. Generally speaking, the best results are obtained when attachments are made just below the lowest major lateral branch on a given scaffold branch.

Pressure exerted on the branch must be great enough to keep it from slipping, but not so great that it causes damage. Optimum pressure depends on the age of the wood, the size of the limb and the construction of the claw. The pressure on the claw of the shaker used in the trials could be set from 800 to 1,500 pounds per square inch. A setting of 1,200 p.s.i. was used. This proved satisfactory in most instances.

Bark damage due to slippage or pressure of the claw varied from none to quite serious. Some growers feel that while it is objectionable it is not particularly harmful. Others say that the cumulative effect of attachments made at the same point in successive years might prove quite serious. Bark damage can be prevented by wrapping attachment points with cloth, belting or rubber. Research is being conducted to develop a claw that will eliminate all or most of the damage. Studies are also being made to determine the seriousness of the bark damage.

The use of a boom-shaker does not appear to cause root damage. Most attachments were made from 6 to 8 feet above the ground. When the "shake" was applied, that part of the tree which was above the ground absorbed most of the shock and roots did not appear to suffer any ill effects.

Collecting units used with a boom-shaker usually extended from 10 to 12 feet from the trunk of the tree. The diagonal distance to a corner may be as much as 17 feet. Therefore the boom must extend for at least 17 feet in front of the tractor.

Maneuvering a tractor-mounted boom is difficult and involves careful steering and numerous changes in direction. Tractors equipped with power steering and reversible (shuttle) gears are recommended.

Other Shakers. Many growers and orchard equipment manufacturers have become interested in the possibilities of mechanization. Several units have been made and others are being planned. Although relatively small, inexpensive self-powered shakers might lack the capacity needed by large commercial growers, they could probably be used to advantage in small orchards, young plantings, hilly terrain and closely-spaced blocks. Some shakers being developed may prove practical, and certainly existing equipment will be improved.

Collecting Equipment

A satisfactory method of collecting the fruit is necessary. An effective collecting unit must catch the falling fruit and convey it into an initial container with a minimum of damage. The unit must be mobile enough to be easily moved from tree to tree as rapidly as the shaker is moved.

Six types of collecting units used in commercial plantings are described below. It is hoped that a discussion of these units will enable growers to select or develop units which will suit their needs.

Light Weight Rectangular. The collecting unit used in 1957 for preliminary trials consisted of a 12 x 24-foot piece of 6 ounce canvas, supported at the four corners and at the mid-point of the side next to the tree when the unit was in use (Fig. 3). This unit sloped away from the tree to an opening through which the cherries flowed into lugs placed on the ground. Two units were required to collect the fruit from a tree.

This frame was useful only in harvesting high-headed trees, since it could not be moved under a low-headed tree. The light weight canvas and lack of a sufficient number of supports allowed cherries to "pocket". It proved much too light for use under commercial conditions.

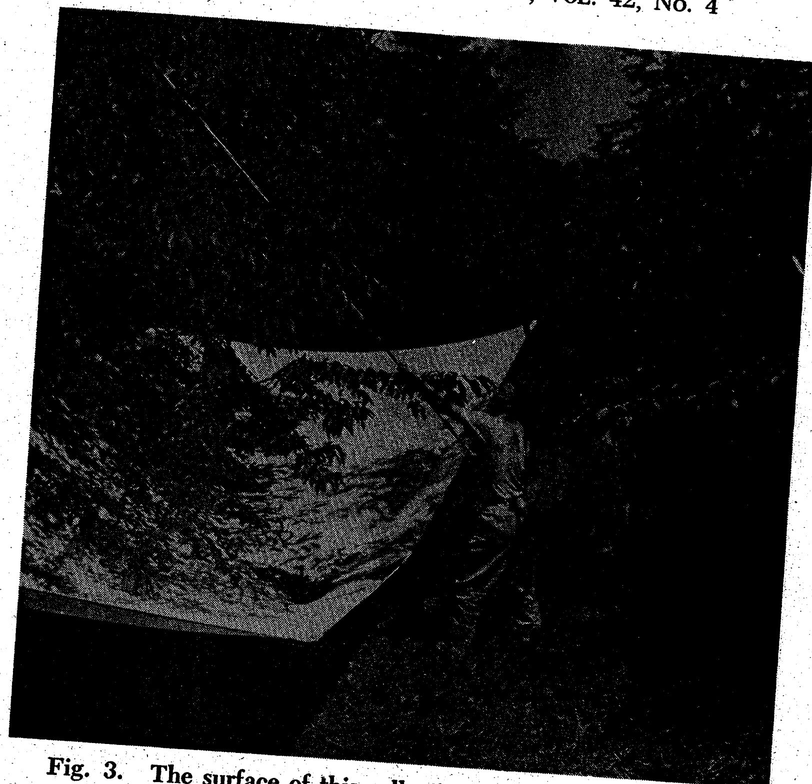

Fig. 3. The surface of this collecting unit sloped away from the tree and could not be used when there were low branches. To operate the hand-held shaker shown here was hard work.

Semi-Circular Folding. A semi-circular collecting unit which could be folded while being moved was used in 1958. It sloped toward a central drain hole located close to the trunk of the tree (Fig. 4). The fruit flowed onto a hand-cranked belt conveyor 8 in. wide which carried it to a point where it was transferred to lugs. The 8-ounce canvas was supported by 10 trussed booms made of thin-walled conduit, each of which was pivoted on the frame near the tree. When it was moved from tree to tree the booms were swung to positions parallel to and close to the sides of the conveyor. This made it easier to maneuver between closely planted trees. An elastic apron attached to the two outside booms formed a "seal" around the tree when the frame was in position.

The unit was supported by three rubber tired wheels 16 inches in diameter. This made it relatively easy to move the unit from tree to tree. The radius of the semi-circular collecting unit was 11 feet.

The cherries drained well with a minimum of pocketing. The high outer edge (5 feet above the ground) made it difficult, however, for the shaker operator to make the low limb attachments sometimes desirable. Two semi-circular frames were used to collect the fruit from one tree. Using two conveyor-equipped frames made it necessary to fill containers at two points on opposite sides of the tree.

Another semi-circular unit, the sides of which directed the fruit into a conveyor, was built in 1959 (Fig. 5). The boom could be attached at points as low as 24 inches from the ground. The collecting unit could be folded to facilitate moving.

Both of the folding units tried required considerable time to fold, move, position and unfold. This characteristic proved undesirable.

Rectangular Collector with Conveyor. Collecting units that could be moved straight down the row were built and tested in 1959 (Fig. 6). Each of the frames was 10 x 20 feet. They were constructed of lightweight tubing and mounted on rubber tired wheels 16 inches in diameter. The slope of each frame was adjustable from the horizontal position to 25°. Two of the four wheels on each unit were castered to facilitate steering. One of the two frames in each set had a hand-

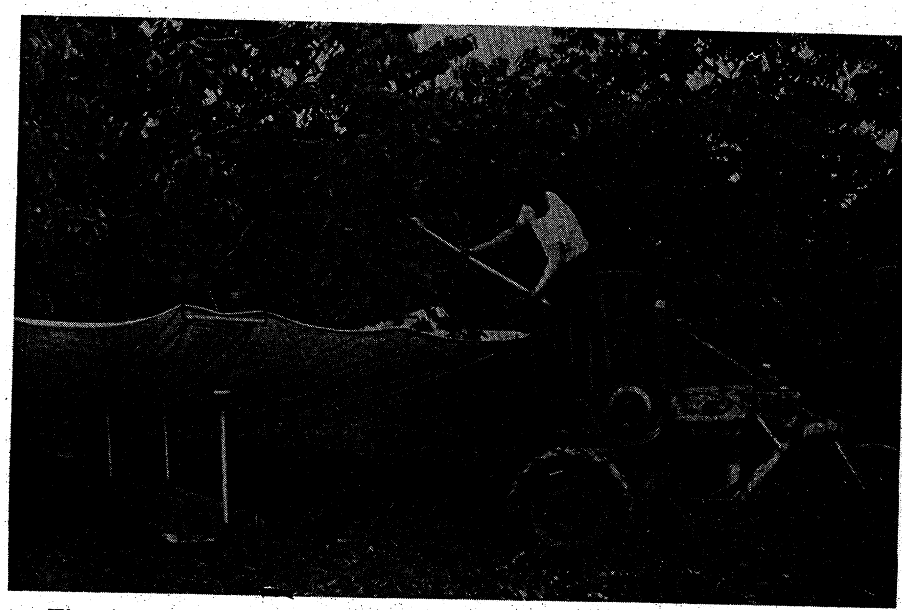

Fig. 4. This semi-circular folding unit was an effective fruit collector, but to fold and unfold it required time and effort. A hand-held mechanical shaker is being used by a worker on a "steel squirrel."

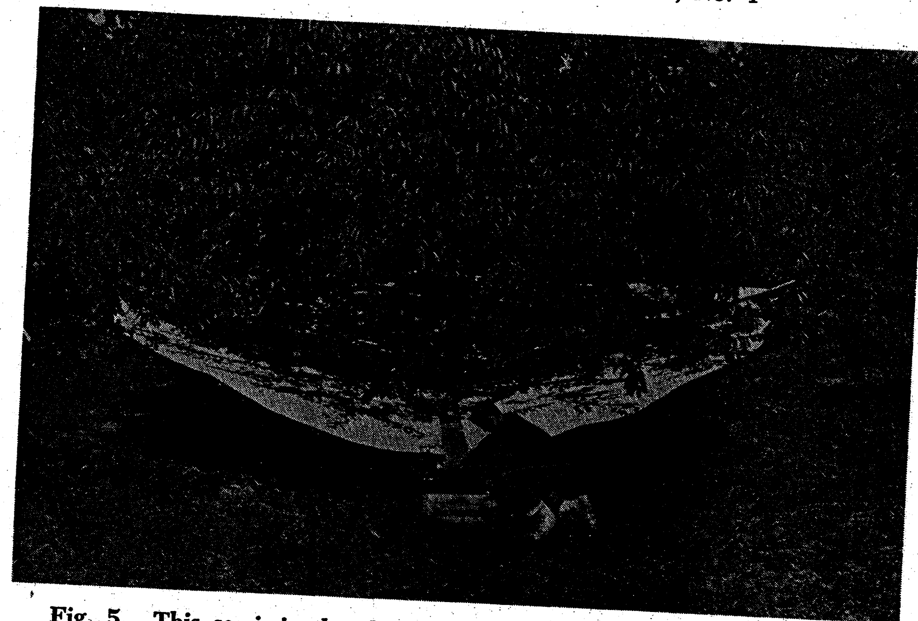

Fig. 5. This semi-circular, low profile unit permitted the shaker operator to make low attachments. However, the folding feature proved undesirable.

Fig. 6. This experimental collecting unit has a conveyor along its lower edge. It has been pushed into position and the other half of the set is being moved in.

cranked conveyor which ran along its lower edge. This was 8 inches wide and 20 feet long. The unit which did not have the conveyor was provided with bridging flaps (one for each side of the tree). They were placed so that they rested on the edge of the conveyor (Fig. 7). All of the separated fruit rolled into this conveyor and was directed into lugs. When the collecting frames were in the "up" position the sides were about 5 feet high at the outer edges. The ends of the frames, however, were open and the shaker could be moved in at a relatively low angle.

Considerable difficulty was encountered with the long narrow conveyor. At times the belt did not track properly, making the hand crank hard to operate.

The 6-ounce twill canvas covering the frames could not be stretched tightly enough to prevent pocketing.

Bridging flaps were not effective in channeling the fruit into the conveyor.

Rectangular Units with Lug Rack. A rectangular collecting unit, similar to the one described above, was made by Mr. Raymond Pappe of Ludington, Michigan. It included two 10-foot lengths of skate roller conveyor instead of the belt conveyor (Fig. 8). Separated cherries

Fig. 7. The "bridging flap", which is part of the right-hand unit, is being placed on the edge of the conveyor which is a part of the left-hand unit.

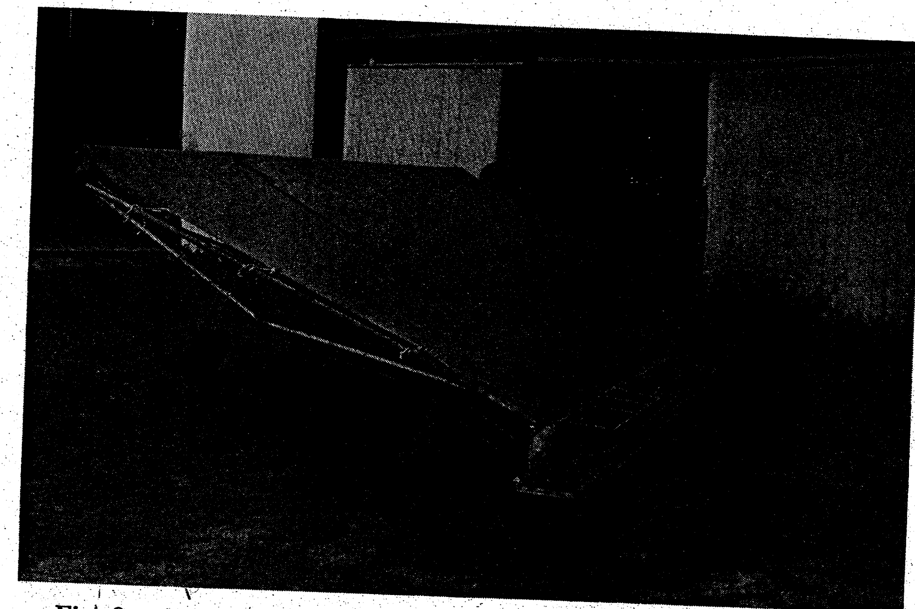

Fig. 8. A collecting unit with a skate roller conveyor along its lower edge. The conveyor holds cherry lugs when the units are being used.

rolled off the collecting unit directly into cherry lugs placed on the roller conveyor and extending along the lower edge of one of the frames. A treated 12-ounce canvas was used to minimize "pocketing." A U-shaped "cut-out" was made in the other frame. This opening was big enough to fit around the trunks of the trees. A hump (18″ wide, 8″ high and 3′ long) also was built into the frame, at the cut-out, to deflect the fruit around the tree trunk and into the lugs. The edge of the frame overlapped the lug boxes on the conveyor. The U-shaped cut-out had no adjustment to compensate for large tree trunks or low-headed trees. When these conditions were encountered, the edge of the collecting frame would not reach the lug boxes and extra lugs had to be placed on the ground to catch cherries which would otherwise have been lost.

All four wheels on these units were castered. This facilitated maneuvering around the trees but caused some steering difficulties when the frames were moved considerable distances.

The two wheels farthest from the tree on each frame had extended swivel shafts on which the edge of the frame could be moved up and down to adjust the angle of the surface. Using lug boxes to collect the fruit caused bruising when the cherries struck the sides of the lugs.

Rectangular Skid-Mounted Frame. Rectangular shaped collecting frames mounted on skids were used in two commercial harvesting operations in 1959. The 12 x 24-foot frames were constructed of 2-inch aluminum tubing and covered with 10-ounce untreated canvas (Fig. 9).

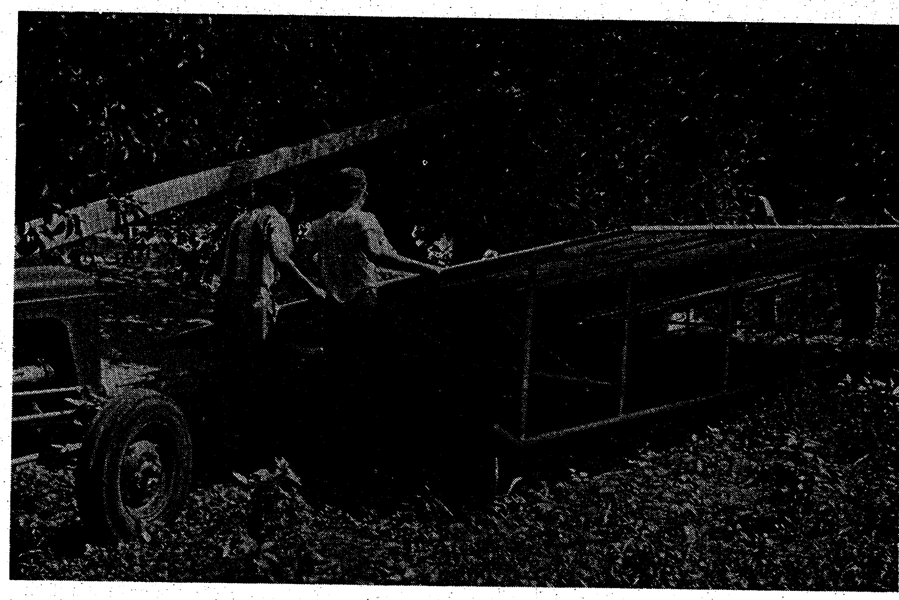

Fig. 9. This skid-mounted collecting unit was used effectively in one commercial orchard during experimental mechanical harvesting of cherries.

The canvas was stretched on the frame by using tent rope tighteners. Both halves of the set had fruit-deflecting humps at the middle of the lower edges. The collecting frames sloped toward the trees and emptied into specially made troughs (boxes) lined with canvas. These troughs were 5½ feet long, 18 inches wide and 6 inches deep. The canvas "liners" were attached to the "long" edges in such a way that they did not touch the sides or the bottom of the box. This provided a yielding surface which the cherries struck as they rolled into the trough. The containers had hinged doors at one end that facilitated emptying.

Fruit in the troughs was emptied into lugs or tanks containing cold water. This was performed after the tree had been finished and the collecting units moved ahead.

This collecting equipment was simple and had no moving parts. It cost less than that of the frames provided with conveyors. The troughs were wide enough to allow some latitude in placing the frames under low-headed trees.

The light-weight frames on skids worked well in flat, clean cultivated orchards, but the crew was tired at the end of an 8-hour day. Skidding the frames and lifting the troughs was hard work. The wood troughs used in the trials were heavy and cumbersome. Collecting units made from metal tubing and canvas are much lighter and should prove just as serviceable. The untreated canvas tended to shrink at night and stretch during the daylight hours. This required frequent rope-tightener adjustments.

Rectangular Leg-supported Frames. Simple non-rigid rectangular collecting frames, 12 x 24-feet, were made and used in two commercial harvestings. One set of frames was made from steel tubing, the other one from 1-inch galvanized pipe. In each case the canvas was laced directly to the frame. The outer edges of the frames were supported by hinged metal legs (Fig. 10). The surfaces sloped toward and rested on a row of lugs placed under the trees to be harvested. These units were comparatively light and deflected the separated fruit directly into lugs. They were lifted and carried from tree to tree. Although

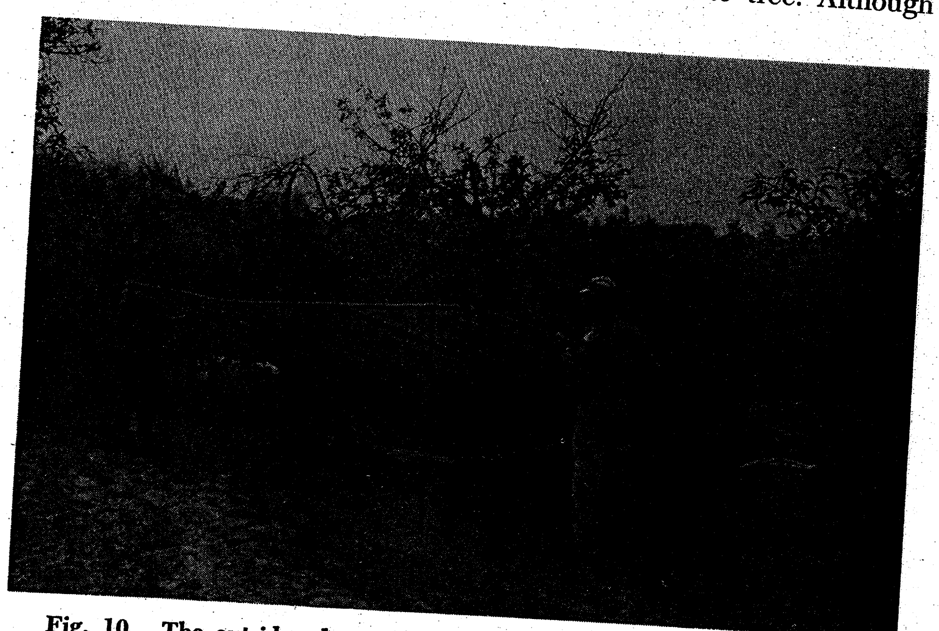

Fig. 10. The outside edge of this cherry collecting unit was supported by adjustable metal legs.

the frames were relatively light, lifting and carrying them frequently proved to be hard work.

Flexibility of the frames caused the canvas to pocket and the lacing of the canvas made it difficult to take up the slack.

Placing the lugs on the ground was unsatisfactory when trees were mounded or the ground uneven.

No provision was made to deflect the fruit around the tree trunk. This resulted in some loss of fruit. Extra labor was required to place the lugs at the next tree before the frames were moved.

Handling Equipment

"Handling" the fruit begins when the separated cherries have moved from the collecting unit into a lug, trough, conveyor or other container and ends when it arrives at the processing plant. "Handling equipment" means conveyors, lug tanks and/or other devices used during the handling operation.

All commercial fruit handling damages the product. Cherries are tender fruits and must be handled with care to maintain acceptable grades. Although injury may occur at any time during the 12- to 24-hour period which usually elapses between picking and processing, the most critical period is the 2-hour interval immediately following the time the cherries are separated from the tree. During this time, friction, temperature of 60°F. or higher and/or pressure cause scald and other types of injury which affect appearance, quality and grade.

Effective cherry handling equipment must produce a minimum of friction and pressure on the fruit. Lowering the temperature of the fruit increases the effectiveness of the equipment.

In an effort to develop handling equipment which provides all, or at least most, of the desirable characteristics mentioned above, the six combinations of equipment described below were tried.

Lugs. When lugs were used, a line of them was placed side by side on the ground (in the row) under the tree to be harvested or on a rack built along the lower edge of one of the collecting units (see discussion of "Rectangular Units With Lug Rack" page 13). When the lugs were placed on the ground, two inclined plane collecting frames were placed so that the cherries which fell rolled into the lugs. Best results were obtained when the tree ahead of the one being harvested was "lined" with lugs so that the collector could be moved ahead as soon as a tree was finished. When the units were moved, the cherries in partially filled lugs were poured together and empties moved ahead. Filled lugs were left in the row. When a load had been accumulated, they were placed on a truck and moved to the processing plant.

Troughs and Lugs. Wooden boxes, "troughs" were 5½ feet long, 18 inches wide and 6 inches deep. They were provided with handles and a hinged door at one end (Fig. 11). When these containers were used, two units were placed end to end (in the row) on each side of the trunk of the tree to be harvested. The cherries rolled from the collecting units into the troughs. When the frames had been moved to the next tree (under which a second set of troughs had already

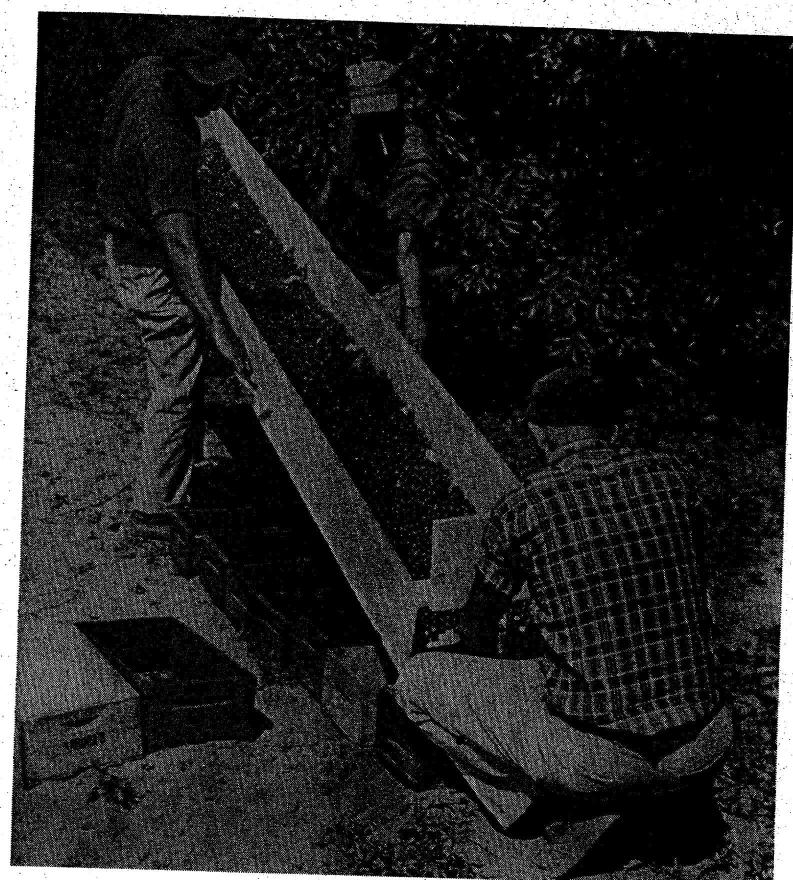

Fig. 11. This is one of the troughs in which cherries were collected. The handles and hinged door facilitated emptying. A trough of the length shown here proved unwieldy and was replaced by two 5½ foot units. Note that the amount of leaves and twigs which came off with the cherries is relatively small.

been placed), the filled units were emptied into lugs and moved to the tree ahead. When a load of filled lugs had been accumulated, they were loaded onto a truck and moved to the processing plant.

Conveyor and Lugs. When this combination of equipment was used, a hand-cranked conveyor was attached to the lower edge of one of the collecting units (Fig. 12). The cherries which fell onto the unit rolled into this conveyor. Once on the conveyor the cherries were moved to the end and transferred into lugs, then transported to the processing plant.

Fig. 12. The hand-cranked conveyor attached to the lower edge of one of the collecting units enabled the workers to move the cherries to a point at which they could be transferred to lugs.

Lugs and Tanks of Water. The fruit was collected in lugs as outlined above. Cherries were poured from the lugs into tanks containing cold water (Fig. 13). Tanks were moved to the processing plant by means of trailers or trucks.

Troughs and Tanks of Water. In this case, the cherries were collected in troughs as described above, but instead of being emptied into lugs the fruit was poured into tanks containing cold water and transported directly to the processing plant.

Fig. 13. This 4′ X 4′ X 4′ tank can be moved through the orchard with lift equipment. Using such a tank makes it possible to cool mechanically harvested fruit quickly.

Conveyor and Tanks. In this system, cherries are collected in a conveyor, but instead of being transferred to lugs they are moved directly from the conveyor to tanks containing cold water and taken to the processing plant on trucks.

Handling Equipment Compared. The most important factors to be considered in deciding the best combination of equipment are: 1) Effect on quality, 2) labor cost in using the equipment and 3) difficulty of physical labor involved.

If care is taken, mechanically harvested cherries can be handled in lugs or troughs with a minimum of damage. However, the workers who move and stack the filled containers in hot weather tend to become tired, careless and difficult to manage. Advantages of water handling[2] (see discussion on "Quality can be maintained" page 21) are so significant that "conveyor and tanks," "troughs and tanks" or "lugs and tanks" are ranked one, two and three respectively.

[2]See U.S.D.A. Circular No. 891 entitled, "Grower handling of red cherries" for a discussion of this subject.

Using conveyors adds to the cost of the equipment. However, the cost is more than offset by manpower reduction. Not only do conveyors eliminate from one to three workers, but they also minimize the hard work of lifting and carrying lugs and troughs.

QUALITY CAN BE MAINTAINED

The value of a harvesting method depends on how it affects fruit quality and efficiency. There is no market for undergrade fruit. For this reason quality maintenance was emphasized. Checks were made at several points during harvesting, handling and processing. Bruising was measured both subjectively and objectively. Grade scores recorded were supplemented, whenever possible, by scores taken by Federal-State inspectors. Causes for down-grading were ascertained and, when feasible, corrective changes were made.

Unlike hand pickers, mechanical shakers cannot be selective. They separate practically all of the cherries produced by a given tree. The grade of mechanically harvested cherries is affected by 1) the quality of fruit on the tree, 2) the amount of mechanical injury which occurs during harvest and handling, and 3) the number of stems which remain attached. Although the presence of a stem on a cherry does not affect its quality, it must be removed during the processing operation. Because of this, stems are counted as defects in determining grade.

Grade Scores Analyzed. Analysis of representative grade scores may prove helpful to growers considering mechanization. Table 1 gives grade scores of unsorted, mechanically harvested cherries from four orchards in West Central and Northwest Michigan. Scores ranged from 79 to 95.

Orchard A, the first one harvested in 1959, was graded 84 and the biggest defect was bruising. Seven percent were seriously bruised. Injury was due to faulty operation of collecting equipment. Bruises were caused by 1) pockets in the collecting unit, 2) handling necessary when cherries piled up at poorly designed deflectors, 3) faulty operation of the conveyor belt, 4) careless filling of lugs, and 5) hard surfaces of parts of the collecting unit on which some of the cherries fell. Approximately 5 percent of the collecting surfaces were made of wood, metal or hard rubber. In subsequent tests improvements

TABLE 1—Grade scores (a) of unsorted (b) mechanically-harvested red tart cherries

Grade factor	Orchard			
	A(*c*)	B(*d*)	C(*e*)	D(*f*)
Harvested cherries which were defective (decay, wind whip, etc.) before separation	Percent 6	Percent 5	Percent 11	Percent 2
Cherries bruised during harvest	7	2	3	1
Cherries harvested with stems attached	3	2	7	2
Grade score....................	84	91	79	95

(*a*) Grade scores were determined by the investigators during the 4-hour period following separation. All lots were scored also by Federal State inspectors. In each case the Federal State grades were equal to or higher than those recorded by the investigators.
(*b*) Data are based on all of the mechanically-separated cherries. When cherries are picked by hand, the workers often discard some of the defective fruits.
(*c*) Data are based on the averages of 16 2-pound samples from 16 trees chosen at random.
(*d*) Data are based on the averages of 5 2-pound random samples from the combined fruits from 14 trees.
(*e*) Data are based on the averages of 15 2-pound random samples from the combined fruits from 15 trees.
(*f*) Data are based on the averages of 8 2-pound random samples from the combined fruits from 8 trees.

were made. One of the devices used to prevent bruising was a canvas deflector which prevented cherries from falling vertically into the trough.

In orchard B and C, grade scores were adversely affected by inferior on-the-tree quality. Grade cannot be improved by harvesting. It can at best only be maintained. Thus, the highest possible score of unsorted cherries from orchard C was 89 percent. Eleven percent of the cherries had defects such as wind-whip, scars and decay before they were separated. Seven percent of the cherries came off the trees with stems and 3 percent were bruised in harvesting. The resulting grade was 79. The grade could have been raised to acceptable standards by hand sorting.

Good results were obtained in orchard D where unsorted, mechanically harvested fruit graded 95. On-the-tree quality was excellent, bruising was held to a minimum and relatively few of the harvested cherries came off with stems.

In orchards B and D, mechanically harvested cherries were less seriously bruised than commercially hand picked cherries from the same orchard. The opposite was true in orchards A and C.

Trash. The amount of trash (leaves, twigs, stems and other foreign material) was relatively small. It was floated off during the soak period and posed no serious problem. Old trees yielded more trash than younger ones. Probably first shaking separates trash that has been accumulated during several seasons. Subsequent shaking probably will cause less trash to fall.

Stems. Causes for variation in the number of stems remaining on harvested fruit are not known. In three of the six orchards studied only about 2 percent of the cherries had stems. In the remaining three orchards, however, 7 percent of the mechanically picked fruit came down with stems. In some tests stem attachment was found to vary with the maturity of fruit and the nature of the shaking. The number of attached stems decreased as cherries became riper and mechanical shaking yielded fewer with stems than did manual shaking. The possibility of a relationship between stem attachment and the amount of nitrogen in the soil or tree is being investigated.

In the processing plant, most stems remained attached to the cherries as they were soaked and conveyed along the processing line. The cherries with stems, however, were conspicuous and could be removed during the sorting operation provided, of course, that the percentage was not high. In some tests a mechanical de-stemmer was placed in the processing line. Although this machine removed practically all of the stems, its capacity was limited.

Culls. Attempts to improve quality by removing defective fruit prior to harvest have thus far proved unsuccessful. Although a short preliminary shake removes many of the defective cherries, it also separates a considerable number of high grade fruit. In some instances mechanical shaking enables operators to improve grade, because most of the cherries which do not separate readily (approximately 5 percent) are small, lightly colored and immature.

Bruises. In harvesting cherries with machines, the fruit must be separated, collected and handled. It was found that cherries could be mechanically separated and collected with less bruising than normally occurs when the fruit is picked by hand. In other words, mechanical shaking, falling through the tree, striking the collecting unit and rolling over it to the initial containers caused comparatively little bruising.

Mechanically separated cherries had less stem-end damage than those carefully handpicked. In four tests in two orchards, an average of 88 percent of the handpicked cherries had slight tearing of the skin, bleeding, and pulled-out pulp tissue at the point of stem attachment; the corresponding value for mechanically harvested fruit was 64 percent.

Scald. Proper water handling minimizes scald and helps maintain on-the-tree quality. The effect of handling machine-picked cherries in water was determined by placing the cherries immediately after harvest in (1) water at 40° - 45° F., (2) water at 55° - 60° F., and (3) lugs at 80° - 85° F. Five hours later at the processing plant the cherries were transferred to a soak tank containing water at 55° F. After being soaked for 16 hours, the amount of scald in the various lots was 1 percent, 6 percent, and 13 percent, respectively. The data are averages obtained by repeating the experiment four times on cherries from two orchards. The lots ranged in size from 20 to several hundred pounds.

Similar results were obtained with cherries harvested by hand pickers. Results show that scald can be inhibited almost completely by proper use of the water-handling. Cherries improperly handled in warm water (70° - 80° F.), however, may exhibit as much or more scald than cherries handled in lugs. Success depends largely on the temperature of the water and the time which elapses between harvesting and cooling. The colder the water and the shorter the time, the better the results.

Processed Samples. Several months after heat processing, sample cans of mechanically harvested fruit were opened and graded. Mechanically harvested fruit compared favorably with hand picked fruit. The color of the fruit which had been handled in cold water was slightly superior to that of fruit handled in lugs. All samples met the legal requirements for U. S. Grade A pack.

MECHANIZATION SAVES TIME, MONEY AND LABOR

Time, motion and cost studies were made of mechanical harvesting in six orchards of 540 trees and the 1,161 lugs of cherries which they produced. Results obtained in the experimental blocks were supplemented by records kept on 2,500 additional trees picked with machines.

Figure 14 shows the per-pound labor cost of harvesting cherries. The number of workers involved varied from 4 to 9, depending on the type of equipment used. The figure shows graphically what can

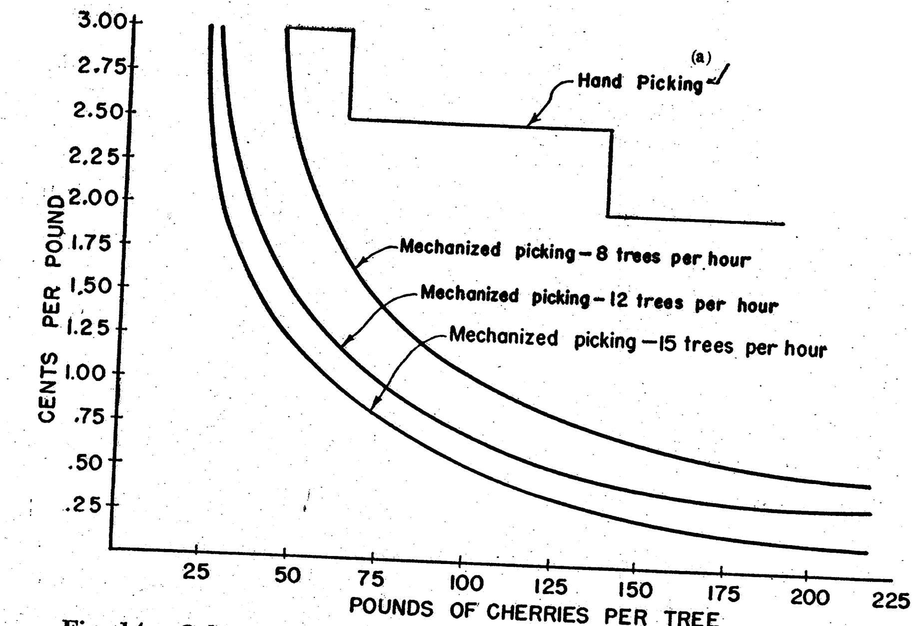

Fig. 14. Calculated per pound labor cost of harvesting cherries (b).

(a) Estimated costs of hand picking—included to make comparisons possible.

(b) Calculations made on basis of a seven-man crew paid $1.25 per hour.

be expected when a crew of seven men is employed. This number was chosen because results indicated that such a crew is large enough to operate with maximum efficiency.

The study showed that it took approximately the same amount of time to shake and collect the fruit from a tree that produced 100 pounds as it did from one that produced 50 pounds. This means that the heavier the crop the less the per-pound cost of harvesting. For example, the per-pound labor cost of harvesting a 4-lug-per-tree crop is about half that of a 2-lug-per-tree crop and approximately a quarter that of a 1-lug-per-tree crop.

The per-pound labor cost is directly affected by the harvesting rate. In orchard C, where the ground was level and the trees high-headed and open, the crew was able to harvest 15.1 trees per hour. In orchard B, the crew averaged 12 trees per hour. In orchard A, where the trees were low-headed and so dense it was hard for the shaker operator to see where he could attach his machine, the average rate was 8.1 trees per hour. Also, the ground cover was so high it interfered with the placing of the collecting units.

Time studies showed that it took from 25 to 44 seconds to make an attachment, shake the limb, release the claw and move to the next branch. Trees that have more than four main scaffold branches take more time and increase per-pound costs. In open trees the time per limb was from 25 to 30 seconds. In dense trees the comparable figures were 40 to 45 seconds. The average number of "sets" (main scaffold branches) on the 540 trees studied was 4.02 per tree.

The average time required to make the attachments and shake the branches in a single tree was 172 seconds. On the average, it took 112 seconds to move the equipment from tree to tree. This means that it took 284 seconds (172 plus 112) or about 5 minutes to harvest a single tree. This rate enabled the crew to do about 12 trees per hour or about 100 trees a day. As pointed out previously, the time required depends on the number of scaffold limbs and the density of the tree and other variable factors. Improved equipment and special pruning should make it possible to do 15 or more trees per hour.

Figure 14 shows the per pound labor cost when trees are harvested by a seven-man crew at rates of 8, 12 and 15 trees per hour. The figures show that increasing the rate pays high dividends.

The labor cost of machine harvesting trees producing more than 50 pounds of cherries is materially less than the cost of handpicking. For example, a grower whose trees produce 4 lugs each (100 pounds), and who harvests them at the rate of 12 trees per hour, pays a labor cost of ¾ of a cent per-pound when the fruit is picked with machines. It is usually necessary to pay hand pickers 2½ cents per pound.

Figure 15 shows the per-pound equipment costs of harvesting cherries mechanically. These figures include depreciation, interest, taxes, insurance and maintenance. Although the equipment should last for more than five years, growers should probably depreciate their harvesting machines on this basis. Improvements will no doubt be made, and the present equipment will probably become obsolete even though it is still serviceable.

The boom-shaker used in 1959 cost approximately $2,700. The cost of the collecting units varied from $300 to $800. Part (⅓) of the cost of the tractor on which the shaker was mounted was also charged to the harvesting operation. In calculating the amounts which appear in Figure 15 a total investment of $4,000 was made. The annual charges for depreciation, interest, taxes, insurance and maintenance came to 30 percent ($1,200) per year. It should be pointed out that

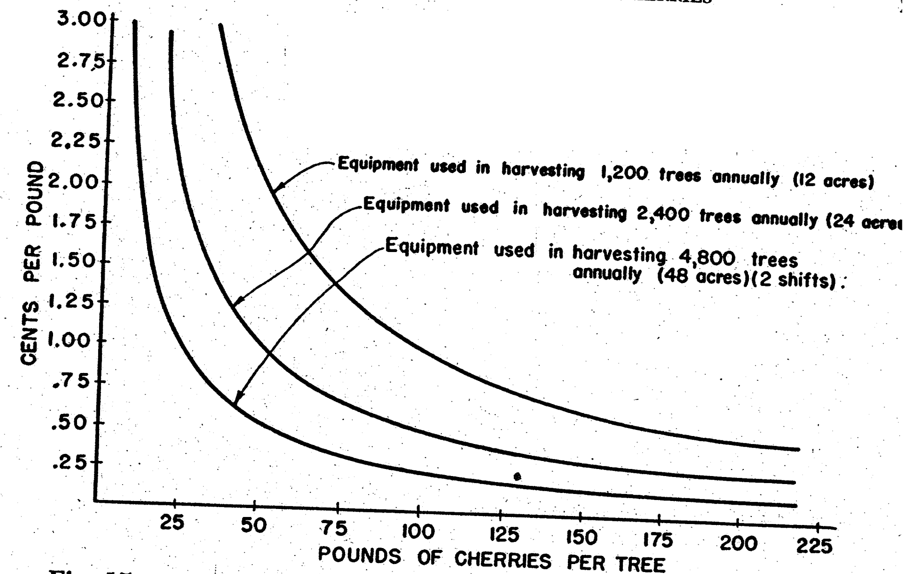

Fig. 15. Calculated annual per pound equipment cost of harvesting cherries mechanically (a).

(a) Depreciation calculated at 20 percent; interest at 6 percent of the average investment; taxes, 2 percent; insurance, 2 percent; maintenance, 3 percent.

the equipment used by the hand pickers needed to harvest a 25-acre cherry orchard costs about $200 annually.

Assuming a production rate of 12 trees per hour, a seven-man crew should harvest 100 trees in an 8- or 9-hour day. If, on the average, the trees produce 100 pounds of fruit, a seven-man crew would harvest as many cherries as 30 to 35 hand pickers. This means that for every 4 or 5 hand pickers only one worker is needed when the cherries are harvested with machines.

The cost of harvesting equipment, per pound of cherries involved, depends on the number of trees and the pounds of cherries harvested during the season. Figure 15 shows the cost when the equipment is used for 24 8-hour days (2400 trees or approximately 24 acres). The figure also shows what would happen if the equipment were used 16 hours a day (two shifts) and also the results that could be expected when used on 1,200 trees — a 12-acre block. The figures show that the equipment should, if possible, be used 16 hours a day. Doing so reduces the per-pound equipment cost by one half.

As in the case of labor costs, equipment costs depended on the number of pounds of cherries per tree. The heavier the crop the less the per-pound cost.

By using Figures 14 and 15, growers can estimate the labor and equipment costs of mechanical harvesting and the number of acres needed to justify the purchase of the necessary equipment. For example, a grower who has 24 acres of trees and a crop which averages 75 pounds per tree would have a labor cost of 1 cent per pound and an equipment cost of .66 cent per pound. This would make a total cost of 1.66 cent per pound as compared to the 2½ cent figure normally paid. Such a grower could not only pay for his equipment in five years, but would also be increasing his returns by .8 cent per pound provided other factors remained the same. He would make an additional saving on housing, insurance, recruiting, etc.

The figures also show that in a 12-acre operation in which the trees produced an average of 75 pounds of fruit the labor cost would be 1 cent and the equipment cost 1½ cent. The total cost would be 2½ cents per pound. In a sense he would just break even. However, he would probably save in recruiting, supervision, insurance and housing.

RESULTS ARE INFLUENCED BY MANY FACTORS

The trials conducted during the past several seasons proved that the effectiveness of a mechanized picking operation is influenced by a considerable number of factors. A short discussion of these factors should lead to a better understanding of the entire subject.

Age of Tree. Young, (less than 10 years) vigorous growing trees are often so dense that it is difficult for the shaker operator to see points at which satisfactory attachments can be made. As the tree grows older the lower limbs tend to be shaded out. This leaves the lower part of the tree relatively open (Fig. 16). An open tree makes it relatively easy for the machine operator to work quickly and effectively.

Pruning. Trees that are to be harvested mechanically should be trained so that they develop relatively high heads and a minimum number (3 to 4) scaffold branches. Low limbs interfere with the placing of fruit-collecting equipment. Branches that touch the collecting surface do not shake enough to cause the fruit to separate. Low limbs should be eliminated early in the life of the tree. Cherry trees begin to open up naturally at about 10 years of age. This tendency can be accelerated by pruning.

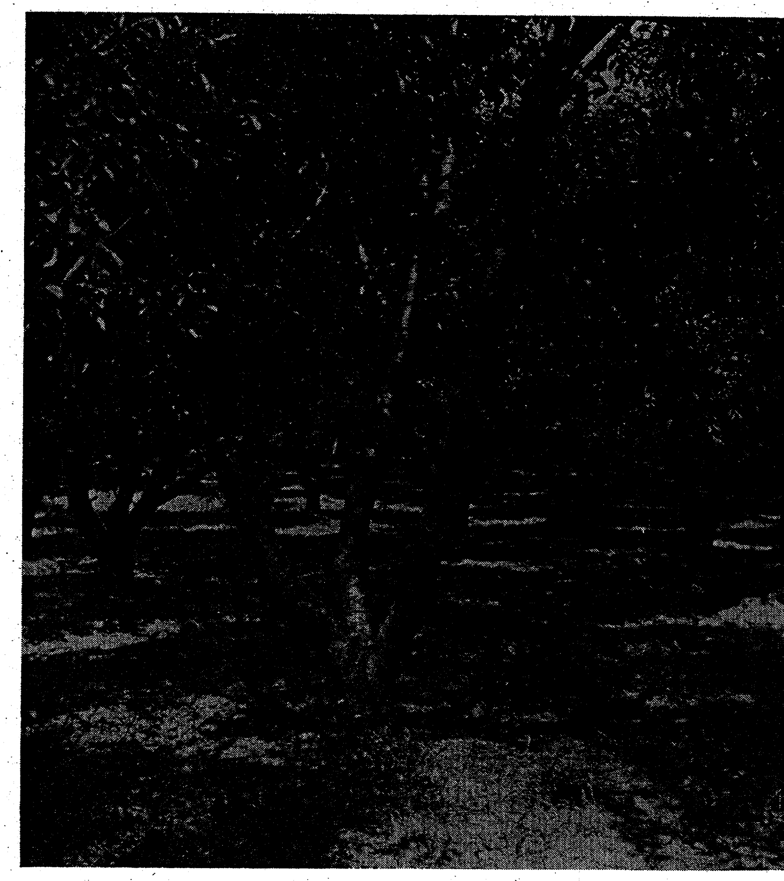

Fig. 16. The boom shaker used in the trials proved effective in orchards made up of trees of this type—open trees with three scaffold branches.

Terrain. The collecting devices so far developed work best on relatively level ground. The mound of dirt thrown up in connection with mouse control programs tends to make the placing of collecting devices more difficult. Ruts, erosion and the furrows sometimes left by orchard tools add to the difficulty of maneuvering the equipment.

Planting Distances. The equipment used in the trials worked best when the trees were spaced at least 22½ feet apart. Wider spacing facilitated the work and will probably continue to be desirable until more readily maneuverable equipment is developed.

Interplanting. Interplanted orchards were more difficult to harvest than solid blocks. Moving the equipment through interplanted orchards increased the time required to do the work and reduced the maneuverability of the equipment. Apple interplants often have low branches that increase the difficulty of moving the equipment from tree to tree.

Spray Program. It has been known for some time that spray materials affect the ease with which cherries can be separated. Further studies will have to be made, however, before definite recommendations can be made. In the meantime growers should realize that the spray materials they use will affect the results achieved by mechanization. The spray program may also affect the percentage of cherries which separate with stems attached.

Fertilizers. There is some indication that the kind and amount of fertilizer used also affects separation. This problem will also have to be studied before recommendations can be made.

Cover. The equipment so far developed worked best in either clean cultivated orchards or in plantings in which the vegetative cover was not more than 2 or 3 inches high. Thick, tall grass or weeds interfered with the placing of the fruit collecting units, the functioning of the conveyors and the handling of containers.

Fruit Varietal Strains. Although no studies have been made of the affect of varietal strain on separation, it is known that strains affect tree vigor, productiveness and color. It seems likely that this factor may also influence ease of separation.

Other Factors. There are no doubt other factors which will affect the results obtained by mechanization. Growers who are contemplating the use of mechanical pickers not only should take all of the known factors into account, but should realize that there may be others which will affect the results achieved.

EQUIPMENT CAN BE USED FOR OTHER CROPS

The cost figures previously presented were based on using the equipment for harvesting only tart cherries. Actually, producers who have mechanical harvesting equipment may be able to use it on apples, plums and sweet cherries. If they do not grow these crops the machines may be rented to others or used in doing custom harvesting.

Plums. Studies have shown that plums can be harvested by shaking. The harvesting cost is relatively low and the grade of the fruit compares favorably with that of hand-picked plums. A separate report on mechanical harvesting of plums is being prepared and will be available from Michigan State University in the near future.

Apples. The results of some preliminary trials indicate that it may be feasible to mechanize the harvest of apples destined for processing outlets. Several hundred bushels of "juice" apples were harvested with machines and placed in containers at a per-crate cost of approximately 3 cents. Improved collecting units may make it possible to reduce the amount of bruising to the point at which apples that are to be made into baby food or apple sauce can also be harvested mechanically.

Sweet Cherries. Studies on harvesting sweet cherries have been made concurrently with those here reported on tart cherries. The methods and equipment used in harvesting tart cherries were tried on several varieties of sweets. A considerable portion of the sweet cherry crop is harvested (for brining) before it is mature enough to go to the fresh fruit market or to the canner. To separate fruit from the tree while it is in this stage of maturity requires rather violent shaking. This treatment caused considerable bruising. A chemical spray which will loosen the cherries and make separation easier is needed. Of the twenty chemicals tried during the past three years, one shows promise and it is hoped that in the near future the mechanical harvesting of sweet cherries may become a reality.

SUMMARY

In 1956 research was initiated to develop equipment and methods for harvesting red tart cherries that would reduce the number of workers required and lower picking costs.

During the 1956, 1957 and 1958 seasons, various types of shaking and collecting equipment and methods were tried. During the 1959 season, the best combinations of equipment (a boom-type shaker and six different designs for collecting units) were used in harvesting approximately 3,000 trees and 6,000 lugs of cherries in six orchards. Time, motion and cost studies were kept on the harvesting of 511 trees and 1,102 lugs of fruit.

On the average, the equipment used separated 95 percent of the cherries. Most of the fruit left on the trees lacked size, color and maturity.

The grade of unsorted mechanically harvested cherries varied from 79 to 95 percent U. S. No. 1. These results show that acceptable grades can be obtained when care and proper equipment are used. Mechanical harvesting in conjunction with proper water handling resulted in the best quality.

Total mechanical harvesting costs varied from ½ cent to over 2½ cents per pound, depending on the size of the crop and the rate at which the work was done. Under the conditions existing in many orchards, mechanical harvesting will enable seven men to do the work of 33 handpickers and reduce harvesting costs by one half.

The equipment and methods used proved satisfactory. However, many improvements will no doubt be made in the near future.

The success of a mechanical harvesting operation depends on such factors as age and structure of the tree, cultural practices, equipment used, handling methods and supervision

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AUTHORS

J. H. LEVIN, Agricultural Engineer, Agricultural Engineering Research Division, U.S.D.A., provided the liaison between the various agencies and individuals involved in the study. H. P. GASTON, Dept. of Horticulture, Michigan State University, directed the horticultural phases of the trials. S. L. HEDDEN, Agricultural Engineer, Agricultural Engineering Research Division, U.S.D.A., designed and supervised the construction of most of the fruit collecting and handling equipment used in the experiments. R. T. WHITTENBERGER, Biochemist, Eastern Utilization Research and Development Division, Agricultural Research Service, U.S.D.A., conducted the quality control studies made during the course of the investigation.